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SSS-A ETU ATTITUDE AND SPIN CONTROL SUBSYSTEM MAGNETIC TEST

J. C. BOYLE

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GSFC — GODDARD SPACE FLIGHT CENTER
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MAGNETIC TESTS

J. C. Boyle
Test and Evaluation Division
Systems and Reliability Directorate

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Goddard Space Flight Center
Greenbelt, Maryland

SSS-A ETU
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MAGNETIC TESTS

Test Engineers: J. C. Boyle and T. N. Roy
Magnetic Test Section

Prepared By: Joseph C Boyle
Joseph C. Boyle
Magnetic Test Section

Reviewed By: C. Leland Parsons
C. Leland Parsons
Head, Magnetic Test Section

Approved By: J C New
John C. New
Chief, Test & Evaluation Division

PROJECT STATUS

This is the report of a preliminary test of the Attitude and Spin Control Subsystem of the Small Scientific Satellite as installed in the Engineering Test Unit Spacecraft.

AUTHORIZATION

Test and Evaluation Charge No. 325-857-11-26-01

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J. C. Boyle
Test and Evaluation Division

SUMMARY

The Small Scientific Satellite (SSS-A) Attitude and Spin Control Subsystem (ASCS) was installed in the Engineering Test Unit Spacecraft and tested in the GSFC Spacecraft Magnetic Test Facility during the period January 6-8, 1970.

The ASCS Subsystem was tested in both the spin-up and spin-down modes, at the nominal spin rate of 4 rpm as well as at 2 rpm and 6 rpm.

With 0 bias, the threshold for full turn-on and for full turn-off was found to be 8100 gammas. With 1000 gammas bias directed north at 4 rpm in the spin-down mode, the full-on threshold was 8100 gammas and the full-off threshold was 8700 gammas.

The magnetic moment developed by the spin-control coil was 2600 pole-centimeters.

Data were also taken in the attitude control mode. A magnetic moment of 9673 pole centimeters was developed. It was demonstrated that this moment remained on over the whole cycle from field levels of 7500 gamma and up at a rotational speed of 4 rpm. The attitude system was also successfully tested at 2, 3, 5, and 6 rpm as well as in the "attitude direct" mode.

SSS-A ETU
ATTITUDE AND SPIN CONTROL SUBSYSTEM
MAGNETIC TESTS

INTRODUCTION

The Small Scientific Satellite (SSS) spacecraft is to be spin stabilized at a nominal rate of 4 rpm. This is to be accomplished by torque produced by interaction between the ambient terrestrial magnetic field in orbit and the magnetic moment generated by an onboard coil. In addition, the spin axis attitude is also to be controllable using a separate coil which produces a magnetic moment directed along the spin axis.

Corrections to spin and attitude are to be made during perigee passes. When the ambient field reaches a certain minimum level, upon command, coil currents are turned on. When the field falls below minimum level, the coil current is triggered off.

PURPOSE

The objective of these tests were to evaluate the spin and attitude control subsystem of the SSS-A. In particular, it was desired to test the ability of the ASCS subsystem to produce the required control torques at various rotational speeds and ambient field levels.

TEST DESCRIPTION

Apparatus

The tests were conducted in the GSFC Spacecraft Magnetic Test Facility. This facility, which is described in Appendix A, utilizes a 40 foot diameter Braunbek coil system to produce a controlled magnetic field of high uniformity over a large central volume.

The SSS-A ETU was mounted on the Mark VI Torque-meter and located at the center of the 40 foot coil system. The orientation of the spacecraft was such that its forward end was uppermost and its boom-mounted spheres were aligned along a North-South line. The x-y axis search coil magnetometer was on the West side of the spacecraft.

During the spin control tests the spin axis of the spacecraft was vertical (see Figure 1). During the attitude control tests, the spin axis was tilted 10 degrees, the upper end of the spacecraft moving toward the West as shown in Figure 2. The c.g. was kept reasonably close to the center of twist of the torquemeter by use of a 20 pound lead counter-weight.

An air-core coil of known coil constant was mounted on the South side of the torquemeter below the spacecraft. The axis of the coil was oriented along an east-west line. This coil was used as a calibrator for the torquemeter.

The torquemeter dash pots were filled to the top with water. The damping achieved was approximately 13% of critical.

All quantities of interest were measured on an eight-channel Brush Recorder located in the truck lock of Building 3-5 at the Magnetic Test Site. The quantities measured were:

- Vector field as determined from X and Y magnetic field components measured by station magnetometers.

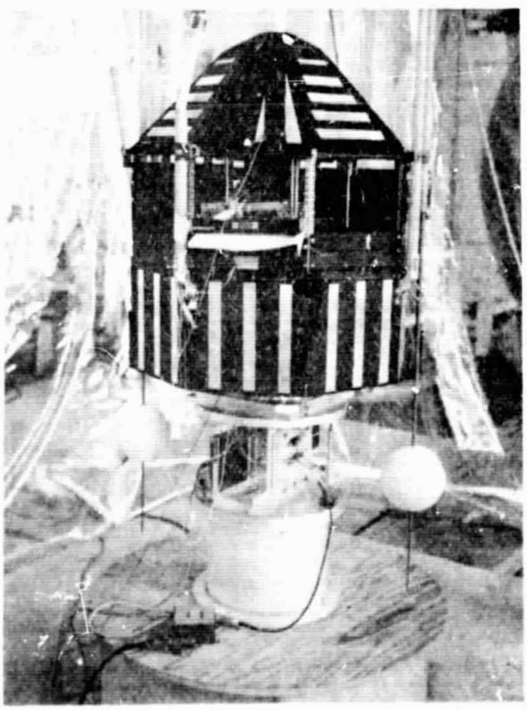


Figure 1. Test Set-up For Spin Mode Tests

Figure 2. Test Set-up For Attitude Mode Tests

- Spacecraft ASCS magnetometer output. The magnetometer probe was aligned in the North-South (X) direction.
- Calibration coil current.
- Spacecraft control coil current.
- Torquemeter output signal.

A sample of these recorded data is shown in Figure 3. In addition, the X component of the applied field and the torquemeter output were also recorded simultaneously on a two-channel Sanborn recorder.

Procedure

The activities performed were as follows:

- Torquemeter calibration
- Spin-up mode test
- Spin-down mode test
- Attitude plus mode test
- Direct attitude on mode test

The details of the procedures followed and the computational techniques used are summarized in Appendix B.

RESULTS AND DISCUSSION

Spin-up – The data obtained with the ASCS subsystem in the spin-up mode are presented in Table 1. Spin axis was vertical. Turn-on occurred when the rotating field level was increased from 7000 to 7500 gammas, the rotational rate being 4 rpm. Turn-off occurred when the field level was reduced from 7500 to 7000 gammas. The torque produced was counter-clockwise with the field rotating clockwise. This is proper for spin-up.

A magnetic moment of 2588 pole cm was obtained when rotating a field of 27,400 gammas at 4 rpm. Corresponding values were 3270 pole cm at 2 rpm and 2990 pole cm at 6 rpm. Calculated moments at lower field levels ranged higher than

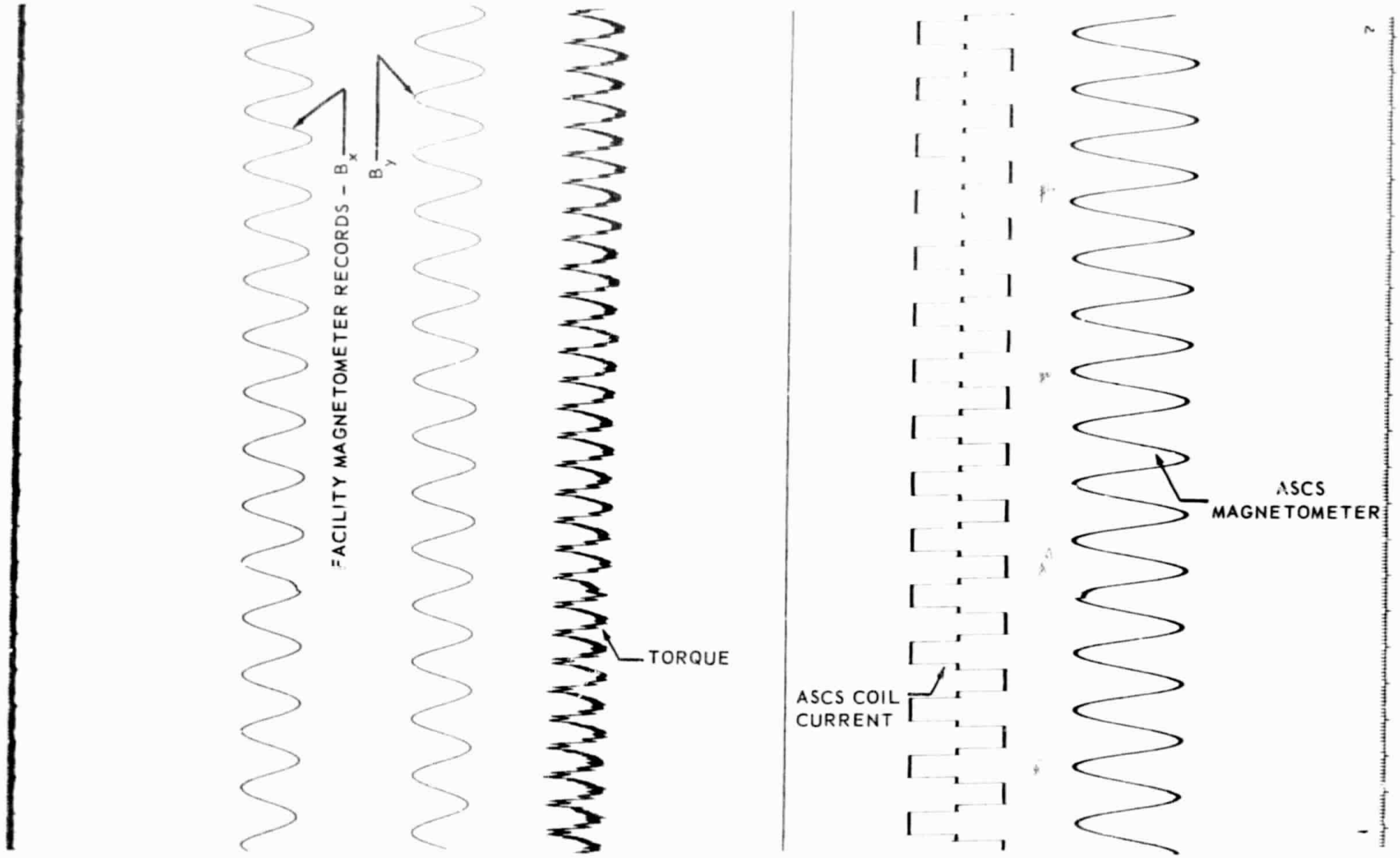


Figure 3. Typical Brush Record in Spin-Down Mode

Table 1

S^3 ETU Torque Test Data - Spin Up Mode

Vector Field (Gammas)	SANB. Sens.	SANB. Defl.	Calibra. d/c/div. @ 2^V CM	Max Torque Dyne-CM	Calc. Moment Pole CM	'On' Time Second/ Cycle	Bias	RPM
7,000	1V/CM	-	39.2	-	-	0	0	4-CW
7,500	1V/CM	24	39.2	470	6270	* 1.3	0	4-CW
8,100	1V/CM	20	39.2	392	4840	2.0 2.3	0	4-CW
8,700	1V/CM	21	39.2	412	4740	2.7 3.0	0	4-CW
9,300	1V/CM	21	39.2	412	4430	3.7 3.8	0	4-CW
10,000	1V/CM	21	39.2	412	4120	4.3 4.3	0	4-CW
10,800	1V/CM	22	39.2	431	3990	4.3 4.3	0	4-CW
11,800	1V/CM	23	39.2	451	3820		0	4-CW
12,700	1V/CM	24	39.2	470	3700	4.8 4.8	0	4-CW
13,700	1V/CM	25	39.2	490	3580	4.9 5.0	0	4-CW
14,800	1V/CM	26	39.2	510	3450	5.1 5.2	0	4-CW
16,000	1V/CM	27	39.2	529	3310	5.3 5.5	0	4-CW
17,100	1V/CM	28	39.2	549	3210	5.5 5.8	0	4-CW
18,300	1V/CM	30	39.2	588	3210	5.7 5.9	0	4-CW
19,600	1V/CM	31	39.2	608	3100	5.9 6.0	0	4-CW
20,850	1V/CM	31	39.2	608	2920	5.9 6.1	0	4-CW
22,000	1V/CM	32	39.2	628	2850	6.0 6.2	0	4-CW
23,200	1V/CM	33	39.2	647	2790	6.2 6.2	0	4-CW
24,400	1V/CM	34	39.2	666	2730	6.2 6.2	0	4-CW
25,350	1V/CM	35	39.2	686	2710	6.2 6.3	0	4-CW
26,150	1V/CM	36	39.2	706	2700	6.2 6.3	0	4-CW
26,700	1V/CM	37	39.2	725	2720	6.3 6.4	0	4-CW
27,150	1V/CM	37	39.2	725	2670	6.3 6.4	0	4-CW
27,400	1V/CM	37	39.2	725	2650	6.5 6.5	0	4-CW
17,000	1V/CM	26	39.2	510	2980	5.5 5.7	0	4-CW
9,300	1V/CM	19	39.2	372	4000	4.5 4.7	0	4-CW
8,700	1V/CM	16	39.2	314	3610	2.6 2.9	0	4-CW
8,100	1V/CM	14	39.2	274	3380	1.8 2.2	0	4-CW
7,500	1V/CM	14	39.2	274	3650	* 1.1	0	4-CW
7,500	1V/CM	22	39.2	431	5750	* 1.8	0	2-CW
8,100	1V/CM	23	39.2	451	5570	2.3 3.2	0	2-CW
27,400	2V/CM	26	39.2	1020	3720	8.5 8.7	0	2-CW
9,300	2V/CM	12	39.2	470	5050	4.2 4.5	0	2-CW
8,700	2V/CM	11.5	39.2	451	5180	3.4 3.9	0	2-CW
8,100	2V/CM	11	39.2	431	5320	2.6 2.9	0	2-CW
7,500	2V/CM	11.5	39.2	451	6010	* 1.6	0	2-CW
7,000	2V/CM	-	39.2	-	-	-	0	2-CW
7,000	2V/CM	-	39.2	-	-	-	0	6-CW
7,500	2V/CM	11	39.2	431	5750	* 1.6	0	6-CW
8,100	2V/CM	12	39.2	470	5800	2.6 2.9	0	6-CW
8,700	2V/CM	13	39.2	510	5860	1.8 2.0	0	6-CW
27,400	2V/CM	26	39.2	1020	3720	4.2 4.3	0	6-CW
9,300	2V/CM	13	39.2	510	5480	2.1 2.3	0	6-CW
8,700	2V/CM	12	39.2	470	5400	1.8 2.0	0	6-CW
8,100	2V/CM	10	39.2	392	4840	1.2 1.5	0	6-CW
7,500	2V/CM	10	39.2	392	5230	* .8	0	6-CW
7,000	2V/CM	-	39.2	-	-	-	0	6-CW

* For S Field Only

NOTES: Spin Coil "on" Current = 82 Milliamperes
Spin Axis was Vertical - No Field Bias
Brush Channel 5 was in use during this test

these values. Since the coil currents were the same in all cases, these moments were actually the same at all field levels and speeds. Difficulties were being experienced with spurious signals due to a grounding problem in Channel 5 of the brush recorder during this mode of operation. This renders these results suspect.

Spin-down — The data obtained in the spin-down mode are presented in Table 2. At 4 rpm with zero bias, turn-on occurred when the rotating field level was increased from 6600 to 7000 gammas. Turn-on occurred only once per revolution (field direction south) until the field level was increased from 7500 to 8100 gammas. When the field was decreased from 8100 to 7500 gammas, turn-on occurred only once per revolution (field directed south) and when the field was decreased from 7500 to 7000 gammas, there was no turn-on.

With a static bias of 1000 gammas directed north, turn-on once per revolution (north field) occurred when the rotating field vector was increased from 6600 to 7000 gammas. Full turn-on occurred when the rotating vector was increased from 7500 to 8100 gammas. As the rotating field was being decreased, once per cycle turn-on (north field) occurred when the field was decreased from 8700 to 8100 gammas. No turn-on occurred when the field was decreased from 7000 to 6600 gammas. The torque produced was clockwise which is consistent with the spin-down mode.

A magnetic moment of 2580 pole cm was calculated for a vector of 27,400 gammas rotating at 4 rpm with 1,000 gamma bias. This is considered the most accurate measure. Moment values of lesser field levels were consistent with this figure.

With zero bias, the moment at 27,400 gammas was calculated to be 2650 pole cm.

At 2 rpm with zero bias, the moment at a field level of 27,400 gammas was 2650 pole cm. At 6 rpm the moment corresponding to 27,400 gammas was 2720 pole cm.

The results for all spin mode testing are listed in Table 3. The best value for spin coil magnetic moment, obtained by averaging the data obtained at the maximum field level of 27,400 gammas in the spin-down mode, is 2600 pole cm.

Attitude – Data were obtained in the attitude plus mode. These are presented in Table 4.

Table 2

S^3 ETU Torque Test Data - Spin Down Mode

Vector Field (Gammas)	SANB. Sens.	SANB. Defl.	Calibra. d/c/div. @ 2^V/CM	Max Torque Dyne-CM	Calc. Moment Pole CM	'On' Time Second/ Cycle	Bias	RPM
7,000	1V/CM	8	39.2	98.0	2240	* 2.0	0	4-CW
7,500	.5V/CM	17	39.2	118	2270	* 2.0	0	4-CW
8,100	.5V/CM	18	39.2	127	2180	2.7 1.8	0	4-CW
8,700	.5V/CM	21	39.2	147	2370	3.2 2.6	0	4-[illegible]
9,300	.5V/CM	22	39.2	157	2320	3.7 3.1	0	4-CW
10,000	.5V/CM	20	39.2	176	1960	4.0 3.6	0	4-CW
10,800	.5V/CM	22	39.2	206	1990	4.4 3.9	0	4-CW
11,800	1V/CM	12.5	39.2	225	2080	4.8 4.3	0	4-CW
12,700	1V/CM	15	39.2	255	2310	5.0 4.7	0	4-CW
13,700	1V/CM	15	39.2	294	2150	5.2 4.9	0	4-CW
14,800	1V/CM	17	39.2	333	2250	5.4 5.1	0	4-CW
16,000	1V/CM	19	39.2	372	2325	5.7 5.3	0	4-CW
17,100	1V/CM	21	39.2	412	2410	5.9 5.6	0	4-CW
18,300	1V/CM	23	39.2	451	2460	6.0 5.8	0	4-CW
19,600	1V/CM	24	39.2	470	2400	6.1 5.9	0	4-CW
20,850	1V/CM	25	39.2	490	2350	6.2 6.0	0	4-CW
22,000	1V/CM	26	39.2	510	2320	6.2 6.1	0	4-CW
23,200	1V/CM	27	39.2	529	2280	6.3 6.1	0	4-CW
24,400	1V/CM	28	39.2	549	2250	6.4 6.2	0	4-CW
25,350	1V/CM	29	39.2	568	2240	6.4 6.2	0	4-CW
26,150	1V/CM	31	39.2	608	2325	6.5 6.2	0	4-CW
26,700	1V/CM	33	39.2	647	2420	6.7 6.3	0	4-CW
27,150	1V/CM	35	39.2	686	2530	6.7 6.3	0	4-CW
27,400	1V/CM	37	39.2	725	2650	6.7 6.3	0	4-CW
8,700	1V/CM	11	39.2	157	2480	3.2 2.6	0	4-CW
8,100	1V/CM	11	39.2	137	2665	2.6 1.9	0	4-CW
7,500	1V/CM	8.5	39.2	118	2220	* 1.8	0	4-CW
7,000	1V/CM	9	39.2	176	2510	*	$1K\gamma N$	4-CW
7,500	1V/CM	9	39.2	176	2350	*	$1K\gamma N$	4-CW
8,100	1V/CM	10	39.2	196	2420		$1K\gamma N$	4-CW
8,700	1V/CM	10	39.2	196	2250		$1K\gamma N$	4-CW
9,300	1V/CM	11	39.2	196	2320		$1K\gamma N$	4-CW
10,000	1V/CM	12	39.2	216	2350		$1K\gamma N$	4-CW
10,800	1V/CM	13	39.2	235	2360		$1K\gamma N$	4-CW
11,800	1V/CM	13	39.2	255	2160		$1K\gamma N$	4-CW
12,700	1V/CM	14.5	39.2	274	2160		$1K\gamma N$	4-CW
13,700	1V/CM	16	39.2	314	2290		$1K\gamma N$	4-CW
14,800	1V/CM	18	39.2	353	2390		$1K\gamma N$	4-CW

*For N Field Only

NOTES: Spin Coil "on" Current = 82 Milliamperes
Spin Axis Vertical

Table 2 (continued)

Vector Field (Gammas)	SANB. Sens.	SANB. Defl.	Calibra. d/c/div. @ 2^V/CM	Max Torque Dyne-CM	Calc. Moment Pole CM	'On' Time Second/ Cycle	Bias	RPM
16,000	1V/CM	21	39.2	412	2575		1KγN	4-CW
17,100	1V/CM	22	39.2	431	2520		1KγN	4-CW
18,300	1V/CM	23	39.2	451	2460		1KγN	4-CW
19,600	1V/CM	24	39.2	470	2400		1KγN	4-CW
20,850	1V/CM	25	39.2	490	2350		1KγN	4-CW
22,000	1V/CM	26	39.2	510	2320		1KγN	4-CW
23,200	1V/CM	28	39.2	549	2370		1KγN	4-CW
24,400	1V/CM	29	39.2	568	2330		1KγN	4-CW
25,350	1V/CM	31	39.2	608	2400		1KγN	4-CW
26,150	1V/CM	33	39.2	647	2470		1KγN	4-CW
26,700	2V/CM	18	39.2	706	2640		1KγN	4-CW
27,150	2V/CM	18	39.2	706	2600		1KγN	4-CW
27,400	2V/CM	18	39.2	706	2580		1KγN	4-CW
10,800	1V/CM	13	39.2	255	2360	3.9 4.6	1KγN	4-CW
10,000	1V/CM	12	39.2	235	2350	3.3 4.3	1KγN	4-CW
9,300	1V/CM	11	39.2	216	2320	2.8 4.0	1KγN	4-CW
8,700	1V/CM	11	39.2	196	2480	2.1 3.6	1KγN	4-CW
8,100	1V/CM	9	39.2	176	2170	* 3.1	1KγN	4-CW
7,500	1V/CM	8.5	39.2	137	2230	* 2.5	1KγN	4-CW
7,000	1V/CM	8.5	39.2	118	2380	* 1.8	1KγN	4-CW
6,600	1V/CM	-	39.2	-	-	-	1KγN	4-CW
7,000	1V/CM	-	39.2	-	-	-	0	2-CW
7,500	1V/CM	8.5	39.2	118	2230	3.9 #	0	2-CW
8,100	1V/CM	10	39.2	137	2420	5.5 3.5	0	2-CW
27,400	1V/CM	37	39.2	725	2650	13.2 12.7	0	2-CW
8,100	1V/CM	9	39.2	137	2180	5.3 3.6	0	2-CW
7,500	1V/CM	7	39.2	118	1830	3.8 #	0	2-CW
7,000	1V/CM	-	39.2	-	-	-	0	2-CW
7,000	1V/CM	-	39.2	-	-	-	0	6-CW
7,500	1V/CM	10	39.2	137	2610	1.2 #	0	6-CW
8,100	1V/CM	11	39.2	157	2670	1.8 1.2	0	6-CW
8,700	1V/CM	11	39.2	176	2480	2.1 1.7	0	6-CW
27,400	1V/CM	38	39.2	745	2720	4.3 4.1	0	6-CW
8,700	1V/CM	12	39.2	157	2700	2.1 1.7	0	6-CW
8,100	1V/CM	12	39.2	137	2900	1.7 1.2	0	6-CW
7,500	1V/CM	10	39.2	137	2610	1.2 #	0	6-CW
7,000	1V/CM	-	39.2	-	-	-	0	6-CW

*For N Field Only

#For S Field Only

NOTE: Spin axis was vertical.

Table 3

Spin Mode Test Results

Mode	Bias γ	Clock-wise rpm	At 27,400 Gammas		Mag. Mom. Pole CM	Full Turn-on Fld. γ	Full Turn-off Fld. γ
			Torque Dyne-CM	Dir.			
Spin-Up	0	4	725	CCW	2650	8100	8100
Spin-Up	0	2	895	CCW	3270	8100	8100
Spin-Up	0	6	820	CCW	2990	8100	8100
Spin-Down	0	4	725	CW	2650	8100	8100
Spin-Down	0	2	725	CW	2650	8100	8100
Spin-Down	0	6	745	CW	2720	8100	8100
Spin-Down	1000γ North	4	706	CW	2580	8100	8700

Average of Spin-Down Magnetic Moment Values = 2600 Pole CM

In this mode the attitude coil turned on at a field level of 7500 gammas at all rotational rates from 2 to 6 rpm. At the 2 rpm speed the coil turned off once each cycle when passing through zero field. At all other test speeds the coil remained on for the full cycle.

Since the axis of the spacecraft was tilted 10 degrees, a component of the moment lay in the horizontal plane and produced a torque when fields were applied. From this the moment along the axis was calculated to be 9673 pole centimeter directed downwards.

In addition to the attitude + the attitude direct mode was also successfully tested.

PROBLEMS

Some difficulty was experienced with grounds on the 8 channel brush recorder and spurious signals appeared on the torque record. This problem was eventually cleared up; however, data taken in the spin-up mode are considered suspect.

Table 4

S^3 Attitude Coil Tests Data

Mode	Field	S.A. Defl.	Torque	Mom. Comp.	Mom. Vect.	CW rpm	Turn-on Fld.	Turn-off Fld.
Att +						4	7500 γ	5500 γ
Att +	60KγN	26.5	1040 CCW	1730 E	9950 Dn	0		
Att +	60KγN	25	980 CCW	1635 E	9400 Dn	0		
Att +	27,400 CW	10.75	460 CCW	1680 E	9670 Dn	4		
Att +						2	7500 (Drop out at 0 Field)	
Att +						3	7500 (No Drop out)	
Att +						5	7500 (No Drop out)	
Att +						6	7500 (No Drop out)	
Att. Dir.	60KγN	25						
Att. Dir.	60KγN	27						

Average Moment = 9673 Pole CM.

NOTES: Vertical axis of S/C tilted 10° West
Calibration constant = 39.2 dyne CM per Division at 2 Volts/CM on Sanborn Record
Attitude Coil "On" Current = 80 Milliamperes

CONCLUSIONS

The spin and attitude control system performed as anticipated. Turn on and turn off field levels and proper direction and magnitude of spin coil moment were verified. The anticipated moment of the spin control coil was 2600 pole cm. The measured value was equal to 2600 pole cm.

Triggering levels and continuous energizing of the attitude coil were successfully demonstrated for the attitude plus as well as the direct attitude on modes. The value of the magnetic moment produced by the attitude coil was anticipated to be 8700 pole cm while the measured value was 9400 pole cm.

APPENDIX A

DESCRIPTION OF FACILITY

The Spacecraft Magnetic Test Facility (SMTF) shown in Figure A-1 provides a controlled magnetic environment in which to carry out magnetic tests of spacecraft or spacecraft components. The 40 foot diameter, 3 axis coil system permits the establishment of zero field or a field of any desired magnitude and direction with a maximum of 60,000 gamma per component. Current regulated power supplies provide stability of ±1 gamma over a 24 hour period while the coil geometry provides uniformity of field within 0.6 gamma over a spherical volume of 3.2 foot radius. Three earth's field magnetometers and associated control systems provide automatic compensation for the daily variation of earth's field.

In addition to the generation of static magnetic fields, the coil current may be programmed so as to produce a resultant vector which will rotate about any desired axis through the center of the coil system at a maximum rate of 100 radians per second. The magnitude of the rotating vector has a maximum limit of 60,000 gamma.

The facility is also equipped with a 5000 pound capacity overhead hoist, a 2000 pound capacity hydroset for gentle handling of delicate spacecraft, a track system and dolly for transporting the spacecraft from the trucklock to the center of the coil system and a turntable at the coil center which is powered to rotate the spacecraft through 360 degrees while it is centered in the coil. The turntable is equipped with an angle encoder so that angular position and magnetic measurements may be synchronized. In addition, a gimbal is available with which to produce rotation of the spacecraft about a horizontal axis.

Fields up to 50 gauss for perming and deperming the spacecraft along one axis can be provided by means of a portable helmholtz coil pair of 9 foot diameter. There is also available a 5 foot diameter coil for applying such fields along a second axis of the smaller spacecraft.

The facility is equipped with a highly sensitive torquemeter located directly below the turntable, which permits the direct measurement of torques resulting from the interaction between the magnetic moment of the spacecraft under test and the field produced by the coil system itself. The torquemeter can be rigged to accept loads to 5000 pounds and to measure torques to an accuracy of 50 dyne centimeters. An additional, portable torquemeter is also available for use with spacecraft weighing up to 850 pounds. With this instrument, small torques have been measured to an accuracy of 10 dyne centimeters.

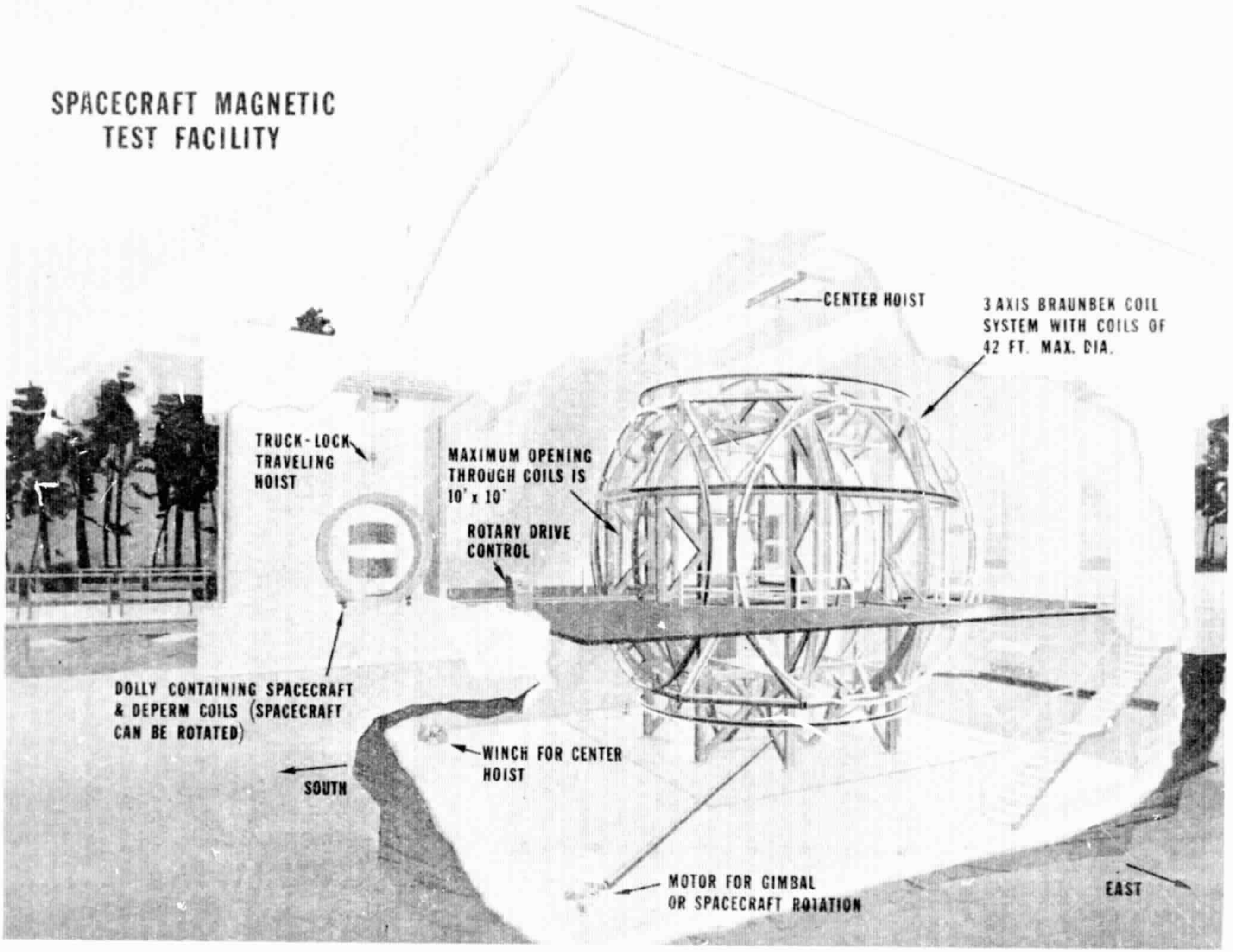


Figure A-1. Spacecraft Magnetic Test Facility

Four tri-axial fluxgate type magnetometers are available and may be used simultaneously to provide meter display, strip chart records or digital print-out records. The positions of the magnetometer probes may be varied to suit the particular needs of the individual spacecraft or sub-system under test.

A photograph of a spacecraft under test in the facility is shown in Figure A-2.

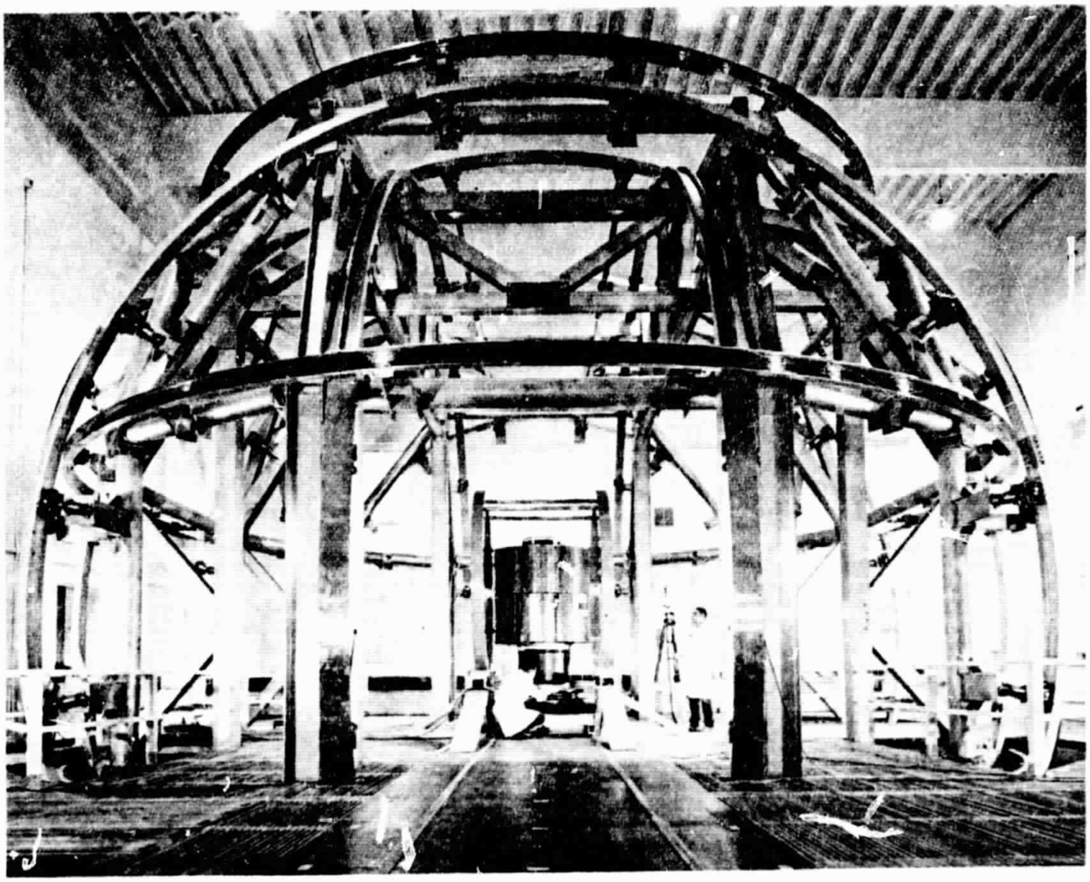


Figure A-2. Spacecraft in the Magnetic Test Facility

APPENDIX B

TEST PROCEDURES AND COMPUTATIONAL TECHNIQUES

CALIBRATION

Two procedures were used to calibrate the Mark VI Torquemeter; one mechanical and the other magnetic. The mechanical calibration made use of a precision weight and bell crank to produce an accurately known torque. With this weight on the outer radius of the bell crank a torque of 1960 dyne cm is realized.

Magnetic calibration makes use of an air core coil mounted on the torquemeter along with the spacecraft. This coil produces a magnetic moment of 1150 pole centimeters when energized with 2 amperes. With a 60,000 gamma field applied at right angles to the coil axis a torque of 690 dyne centimeters is produced.

SPIN MODES

In conducting the spin-up and spin-down tests, the rotation of the spacecraft in the geomagnetic field was simulated by holding the spacecraft fixed and rotating the field. The spacecraft was mounted on the torquemeter which measured the spin torque generated by the control system.

The spin control system has been designed to trigger on when the ambient field as sensed by the on-board magnetometer reaches a certain minimum value and to turn off when the field level drops below this value. The magnitude of the moment is constant but the direction of the magnetic moment depends on the sense of the ambient field. This can be controlled to produce either a spin-up or spin-down torque as desired.

Due to the triggering action, the torque produced is not continuous but consists of a series of pulses. The width of the pulse and instantaneous magnitude of the torque depends on the magnitude of the rotating field vector and the rotational rate. This is illustrated graphically in Figure B-1.

If the torquemeter had an infinitely rapid response rate, the output record would be as shown in this figure.

The actual response rate of the torquemeter is dependent on its moment of inertia, torsional spring rate and damping, resulting in a period of 1.2 seconds per cycle. The damping ratio was measured to be 13% of critical.

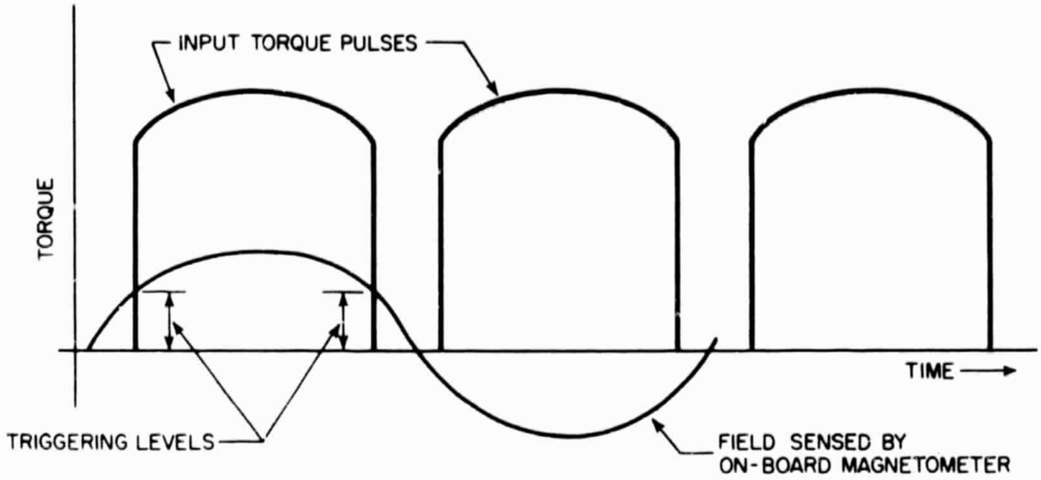


Figure B-1. Spin Mode Torque Pulses

Typical records obtained during spin down testing are shown in Figures B-2, B-3 and B-4. It will be noted that at the higher field values, the torque record resembles the input pulses of Figure B-1 when allowance is made for the resonant response of the torquemeter.

Since the natural period of the torquemeter is 1.2 seconds per cycle and the maximum period of the torque pulses at 4 rpm approaches 7.5 seconds, the peak dynamic response of the meter is essentially equal to the static. The torque corresponding to the peak value of the North-South component of rotating field was calculated on this basis.

ATTITUDE MODES

When energized, the attitude coil produced a moment directed along the vertical axis of the spacecraft. As the torquemeter is only capable of measuring torques due to moments in the horizontal plane, a fixture was used which permitted the axis of the spacecraft to be tilted ten degrees. Then when the attitude coil was energized, a moment component was present in the horizontal plane. The torque due to interaction between this moment component and the rotating field was recorded.

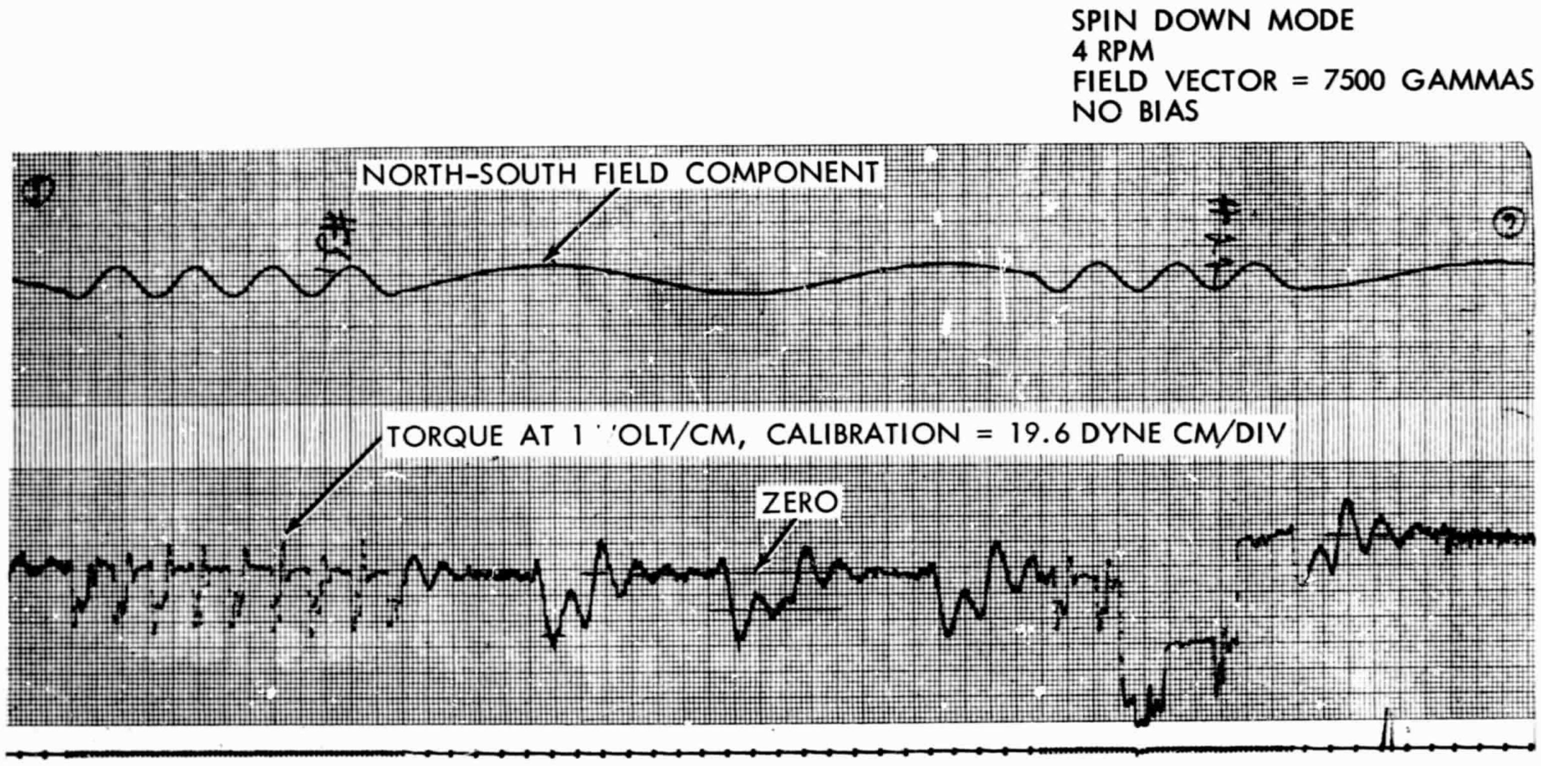


Figure B-2. Sample Sanborn Record – 7500 Gammas

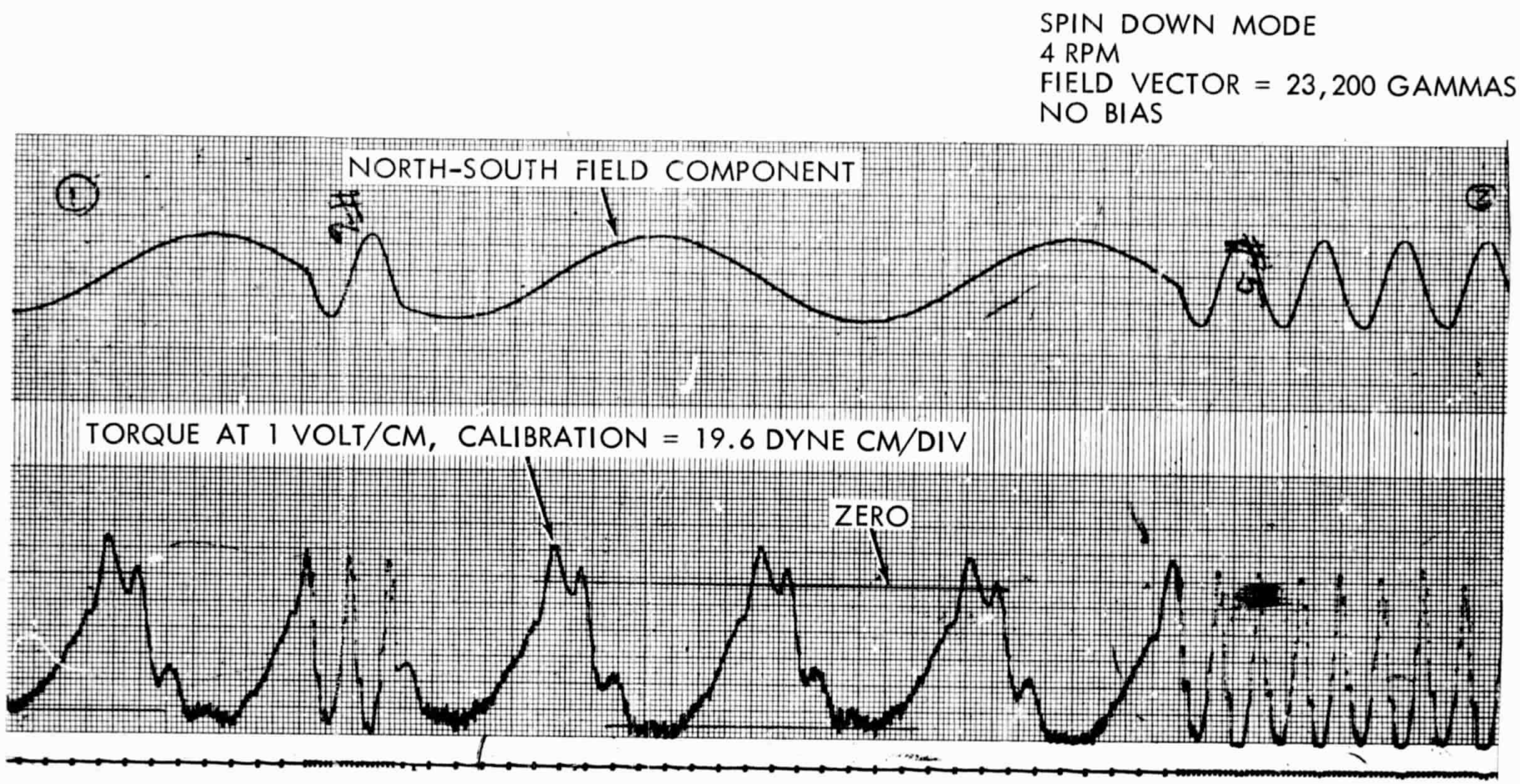


Figure B-3. Sample Sanborn Record – 23,200 Gammas

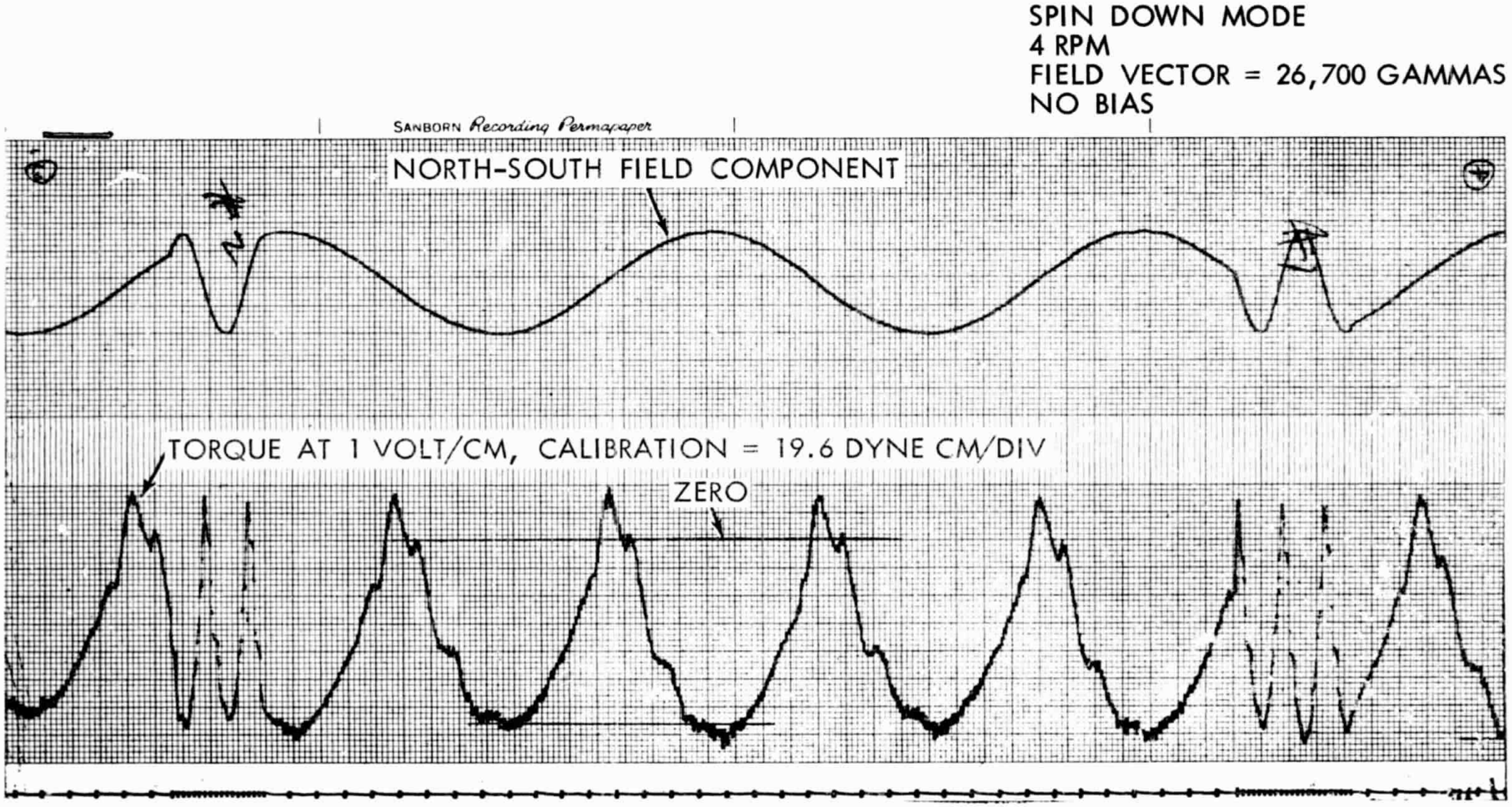
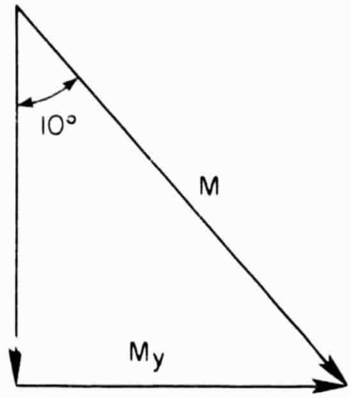


Figure B-4. Sample Sanborn Record – 26,700 Gammas



$$M = \frac{M_y}{\sin 10^\circ}$$

Where

M = Attitude Coil Magnetic Moment
M_y = Horizontal Component of M

In the attitude mode, once triggered on, the coil remained energized during the whole rotation cycle. The torque produced was therefore sinusoidal at the frequency of rotation of the applied field. As the nominal rotational period was 15 seconds per cycle as compared to 1.2 seconds per cycle for the torquemeter resonance, the response was essentially equal to the static value and was calculated on this basis.

APPENDIX C

CHRONOLOGY OF EVENTS

Monday, January 5, 1970

The SSS-A ETU was delivered to the Magnetic Test Site and installed on the MARK VI Torquemeter.

Tuesday, January 6, 1970

The ASCS system was tested in the spin-up mode at 2, 4 and 6 rpm.

Wednesday, January 7, 1970

The ASCS system was tested in the spin-down mode with and without bias at 2, 4 and 6 rpm.

Thursday, January 8, 1970

The ASCS system was tested in the attitude plus and in the attitude direct on mode at 2, 3, 4, 5 and 6 rpm.

Friday, January 9, 1970

SSS-A ETU departed Magnetic Test Site.